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Computer-Assisted Experimentation in Physical Science Education for Moroccan Students

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Keywords

CAEx, physical sciences, high schools, teacher training, barriers

Abstract

CAEx (Computer-Assisted Experimentation) enables real-time experiments to be carried out using a computer; it includes data acquisition and sensor systems, as well as real-time measurement of numerous physical properties. The use of computer-assisted experimentation in the teaching of physics and chemistry in Moroccan secondary schools underwent significant development in 2009. We conducted an exploratory study of 122 physics teachers in Morocco, from the Fez-Meknes Regional Academy of Education and the Casablanca and Guercif provincial directorates, during the 2021-2022 school year. This study was carried out using an anonymous questionnaire. We undertook this study to evaluate the use of computer-assisted experimentation (CAEx) in physics teaching, particularly in secondary schools. The aim was to understand the reasons why some teachers make only limited use of CAEx, despite its supposed pedagogical richness. The data collected in our study, processed using SPHINX V5 software, revealed that most of the teachers surveyed were convinced of the pedagogical benefits of CAEx in the classroom. However, the overall results also confirmed the limited use of this technology. This contradiction is mainly explained by several factors, such as the lack of hardware in secondary schools, the absence of specialised software, student overload, the lack of teacher training and the failure to regularly maintain equipment. The results of this study are important because they highlight the obstacles to the more widespread and effective use of computer-assisted experimentation (CAEx) in physics teaching in Morocco. These obstacles include problems of infrastructure, training, and the availability of the necessary resources. Understanding these challenges is essential for education officials and policymakers, as it could guide the investments and reforms needed to improve science teaching in Moroccan secondary schools.

Introduction

New information and communication technologies (ICT) have rapidly emerged in Morocco, impacting various sectors of society with significant economic, social, political, cultural and educational consequences. Several studies (Abouzaid et al., 2017; Caena & Vuorikari, 2021; Collin & Karsenti, 2013; Kaikai, 2014) have highlighted the scale of these changes. Moreover, ICT can improve the quality and standards of education by integrating it into all phases of learning (Das, 2019). The integration of ICT has also demonstrated a reduction in teacher workload, higher student motivation and increased classroom interaction (Aparicio Gómez, 2020). The findings of studies by Amini and Oluyide (2020), Lubuva et al. (2022), and Shala and

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Grajcevci (2023) confirm that knowledge acquisition is significantly higher when ICT is integrated.

The use of ICT is universally recognised, with notable differences between fields of study (Monroy García et al., 2022). In Morocco, the authorities have made major efforts to disseminate ICT in the education system, with the aim of ensuring equal opportunities in terms of access to information and communication and overcoming barriers in education and training. Royal speeches have stressed the importance of preparing future generations to embrace modern technologies and understand their impact on working practices and culture. Programmes such as GENIE 2006-2013 and the Digital Morocco 2013 plan were launched to equip schools and train teachers in ICT (Omar & Benjelloun, 2013; Ismaili, 2020). Initiatives such as the national Taalimtice website provide information on ICT in education to all stakeholders in the Moroccan education system, while the Strategic Vision for School Reform (2015-2030) focuses on the use of ICT in education (CSEFRS, 2015).

The aim of this research is to analyse teachers' perceptions of the use of CAEx in teaching physical sciences at secondary schools (Abdellah Aroui High School, Salah Eddine El-Ayoubi High School, Ibn Sina High School, etc.) in the Fez-Meknes Regional Academy of Education and the Casablanca and Guercif provincial directorates.

Literature Review

The computer-assisted experimentation (CAEx) system consists of data acquisition tools (chemical and physical) coupled with computer and mathematical analysis software. There are four essential components: the computer, the measurement sensors, the interface, and the software (Girouard & Nonnon, 1999).

CAEx is similar to traditional academic experiments. The only difference is that the process is accelerated by the automatic collection of data by electronic sensors. This data is then processed and presented in real time in the form of graphs or tables. This enables the learner to focus more closely on the scientific subject being studied (Khaldoune, 2015). This approach allows learners to immerse themselves in a real laboratory environment. There, they can design, plan and carry out experiments in various fields such as physics, electronics, chemistry, biology, geology and technology (El Ouargui et al., 2019).

Morocco has also implemented the CAEx system in its secondary schools, gradually equipping schools in 2009 through the acquisition of regional education and training academies. This initiative continued until 2012, with priority given to equipping schools with CAEx (Elazhar & Laaziz, 2012). The study by Menchafou et al. (2023) indicates that most Moroccan physics teachers at the secondary level do not reach the required rate of integrating CAEx due to several challenges, including the need for coaching and training, and lack of coordination between policymakers and practitioners.

Research Questions

The use of the computer-assisted experimentation in physical science education is the focus of this research; at this level, our challenge is expressed by the following questions:

- What is the reality of the pedagogical use of CAEx in high schools?
- Is the number of teachers or classes involved in the physical sciences considered when allocating equipment, to ensure adequate consistency?

- How can physical science teachers, regardless of gender, be trained in the correct use of CAEx in the classroom, and what impact can the gender of the teacher have on the effectiveness of this use?
- What are the obstacles to the effective and efficient integration of CAEx into the teaching-learning process?
- What are the conditions for the successful use of CAEx in high school?
- What are the disadvantages of using CAEx in the teaching and learning process?

Methods

Participants

To achieve the aim of this research, a questionnaire survey was chosen. This approach was chosen because this type of survey allowed us to interview many secondary school physics teachers. The sample was composed of 122 teachers belonging to the Regional Academy of Education and Training of Fez-Meknes and the two provincial directorates of Casablanca and Guercif in Morocco, during the school year 2021-2022.

Instrument

We did exploratory research, through the anonymous questionnaire, to analyse our problem. It consisted of a total of 27 questions (closed and semi-closed questions) divided into the ten following parts:

1. General information.
2. Provincial directorate of education.
3. Material equipment.
4. Use of CAEx.
5. Representation of professors on the usefulness of the CAEx.
6. The disadvantages of using CAEx.
7. The formation of the CAEx.
8. The mastery of CAEx.
9. Barriers to the use of CAEx.
10. The conditions of use of the CAEx.

The survey was administered online using Google Forms, in collaboration with the Regional Academy of Education and Training. The study participants were invited to complete the questionnaires via email and various social networks, with a focus on Facebook groups for Physical Science teachers. To assess the questionnaire's reliability, we calculated Cronbach's alpha internal consistency coefficient, yielding a reliability value of 0.71, signifying an acceptable level of reliability.

Data Analysis

After collecting the responses from the physics teachers, we processed the data using SPHINX V5 software. This software was mainly used for the descriptive analysis of the various questions in the questionnaire.

Results

General Information

Our respondents consisted of 122 science teachers, the majority (83.6%) being men, and the rest (16.4%) women. On the other hand, the largest group of the respondents had an average age between 29 and 40 years, 29.5% of them were younger than 28 and about 24.6% were older than 41. Many respondents to the questionnaire held a bachelor's degree (77.9%), while the remainder were divided between those with a master's degree (17.2%) and those with a doctorate (4.9%). In addition, the main specialisation of the teachers surveyed was physics (77%), while 17.2% specialised in chemistry (Figures 1 and 2).

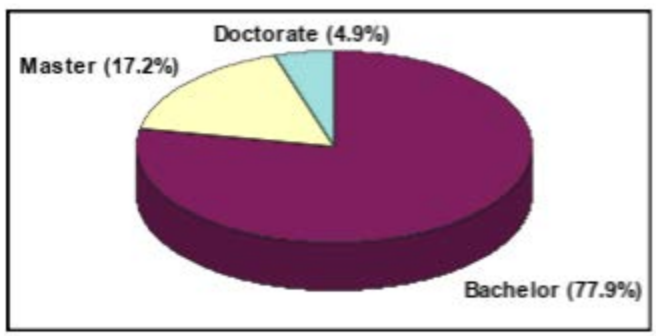

Figure 1: Proportion of physical science teachers according to their academic background

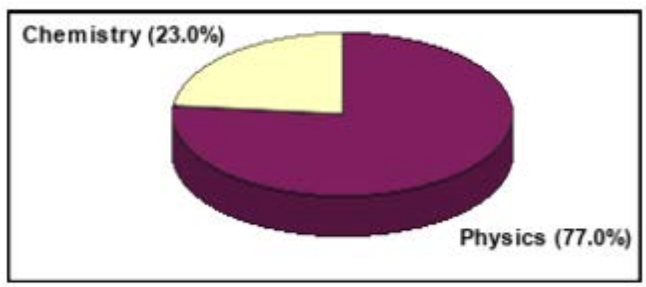

Figure 2: Proportion of physical science teachers by degree specialty

Regarding teaching experience, 31.1% of the respondents had less than four years, 44.3% had between five and 16 years, and 24.6% had more than 17 years (Figure 3).

Figure 3: Proportion of respondents by length of time in education

Provincial Directorate of Education

The survey respondents were distributed according to the provincial directorate of education as follows: 39.3% worked in Fès, 13.1% in Sefrou, 9.8% in Taounate, 8.2% in Taza, 7.4% in Moulay Yacoub, 5.7% in Guercif, and 16.4% in Casablanca. These teachers were spread across numerous lycées in the Fez-Meknes regional academy, as well as in the two provincial directorates of Casablanca and Guercif in Morocco (see Figure 4).

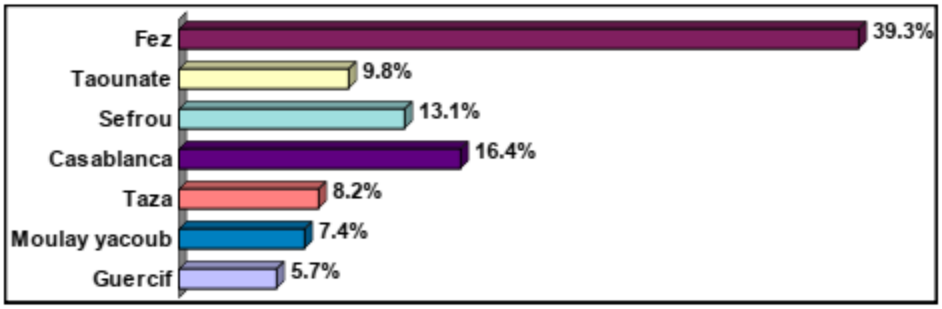

Figure 4: Proportion of respondents according to the provincial directorate of education

The questionnaire was addressed to the physical science teachers of the first (45.9%) and second (47.5%) year of the Experimental Sciences Baccalaureate and Common Core (55.7%) (Figure 5).

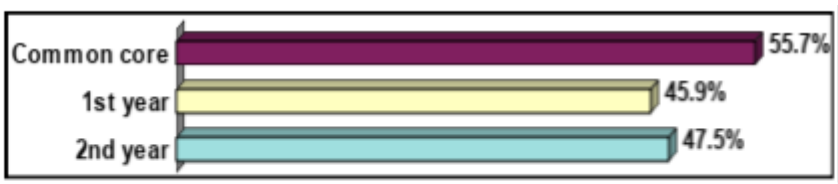

Figure 5: Proportion of teachers according to their teaching level

Material Equipment

According to the statistical results presented in Figure 6, respondents indicated that their physical science classrooms were generally equipped with the following: a computer (86.1%), a video projector (67.2%), a CAEx interface (57.4%), CAEx software (51.6%), and sensors (43.4%). All teachers reported a lack of hardware, which plays a crucial role in the integration of CAEx in the classroom.

These results clearly underline the fact that, despite all our efforts in this area, our state still has not managed to close the equipment gap.

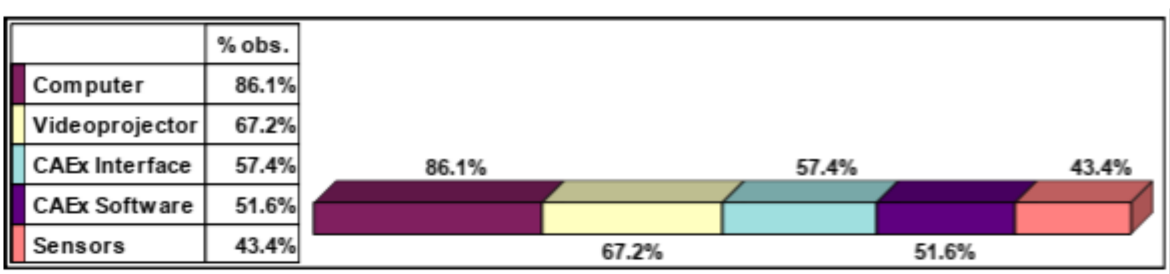

Figure 6: The material equipment of the establishments surveyed

In the Académie de Fès-Meknès and the Direction Provinciale de Guercif, the interface used was Xplorer GLX (82.4%) with Data Studio software (80.3%) (Figures 7 and 8). In contrast, the Casablanca provincial directorate opted for the Labquest interface (17.6%) with Loggerpro software (19.7%) (Figures 8 and 9).

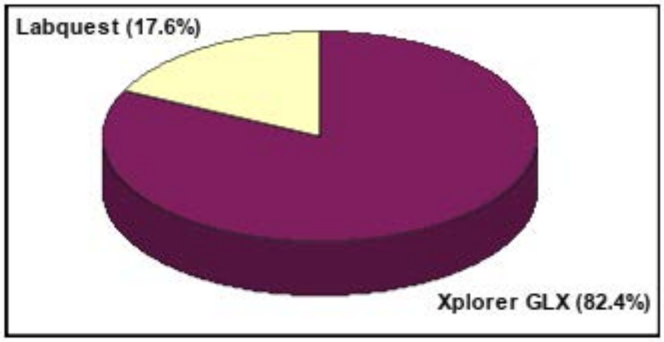

Figure 7: Types of interfaces

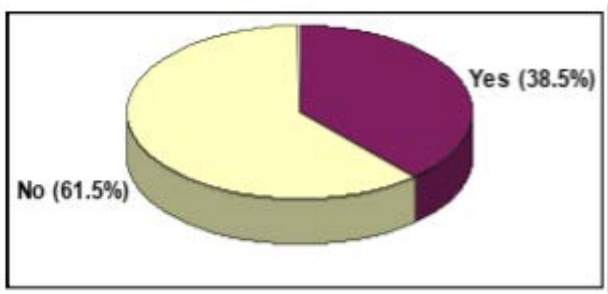

Figure 8: Types of software

Use of CAEx

The results revealed that more than 61.5% of the teachers questioned did not integrate CAEx into their teaching, while 38.5% stated that they used CAEx in the classroom (Figure 9). This survey revealed that the use of CAEx in the classroom by teachers in their practical work was very limited; this observation had already been reported in the regional academies of Marrakech-Safi and Greater Casablanca (Atibi et al., 2017; El Ouargui et al., 2019). On the other hand, the use of CAEx by teachers in Northern European countries is the highest, for example, 90% in Finland (Atibi et al., 2017). According to the French Ministry of Education's Profetic survey, 77% of educators practise computer-assisted experimentation with their students at least once a week.

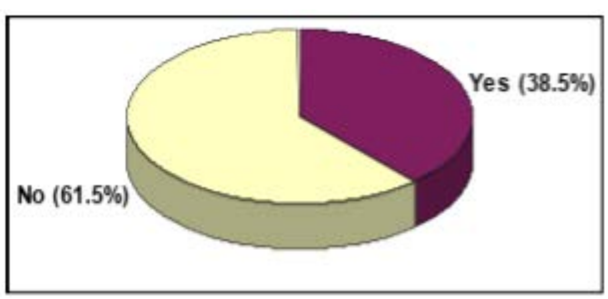

Figure 9: Rate of use of CAE in classroom teaching by teachers

The Chi-Square test of independence was performed to test the following hypotheses:

H_0: Use of CAEx by physical science teachers is not gender dependent.
H_1: Use of CAEx by physical science teachers depends on gender.

The Chi-square test (Table 1) showed a non-significant dependence between physical science teachers' use of CAEx and gender, which confirms the rejection of hypothesis **H_1** and the maintenance of hypothesis **H_0** and allows us to state that the gender variable did not impact CAEx use.

Table 1: Relationship between Respondents' use of CAEx and Gender

	Use of the CAEx		
Gender	**Yes**	**No**	**TOTAL**
Male	33.6%	50.0%	83.6%
Female	4.9%	11.5%	16.4%
TOTAL	38.5%	61.5%	

The dependence is not significant. Chi-Square = 0.73, ddl = 1, 1-p = 60.84%. The values in the table are the total percentages based on 122 observations.

In addition, the result of the Chi-Square test (Table 2) allows us to conclude that there was no significant relationship between the use of CAEx by respondents and the specialty of the diplomas.

Table 2: Independence between the Use of CAEx by Respondents and the Specialty of the Diplomas

	Use of the CAEx		
Diploma	**Yes**	**No**	**TOTAL**
Physics	32.0%	45.1%	77.0%
Chemistry	6.6%	16.4%	23.0%
TOTAL	38.5%	61.5%	

The dependence is not significant. Chi-Square = 1.52, ddl = 1, 1-p = 78.24%. The values in the table are the total percentages based on 122 observations.

With regard the teachers carrying out the practical work mentioned in the school textbooks for core, first- and second-year high school experimental sciences, it is notable that the practical work most commonly carried out was that which required less equipment and preparation time. These included acid-base titration (30.3%), the study of the RLC dipole (28.7%), practical work linked to sound analysis (18.9%), the study of Ohm's law (15.6%), and the characteristics of certain dipoles (10.7%). On the other hand, the determination of the time constant of an RC dipole (4.9%) and the experimental verification of Boyle-Mariotte's law (10.7%) were less frequently carried out, mainly due to the difficulties associated with the conditions under which these practical tasks are carried out in the classroom (Figure 10).

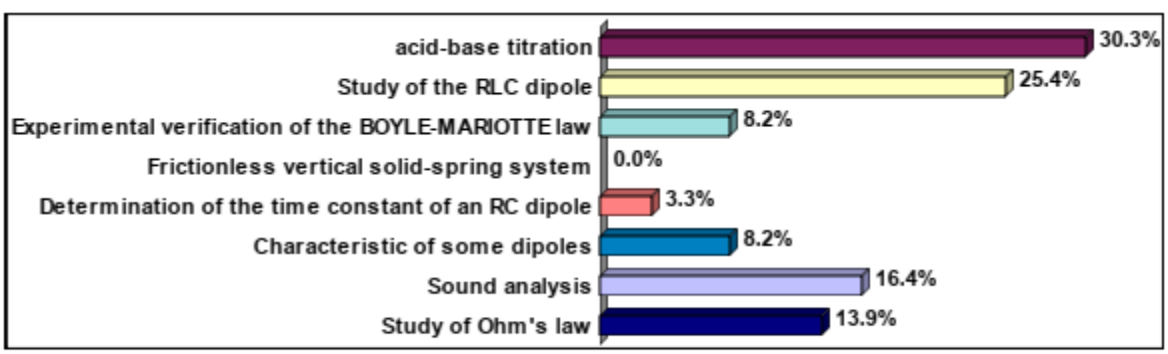

Figure 10: Proportion of practical work carried out in CAEx by physical science teachers

Representation of Professors on the Usefulness of the CAEx

Table 3 indicates the advantages of using the CAEx by teachers.

Table 3: Teachers' Statements on the Benefits of Using CAEx

Statement	% Response
Saves time	71.3 %
Facilitates understanding	77.0 %
Improves student motivation	72.1 %
Approaches to scientific concepts	59.8 %

Respondents reported that CAEx saved time (71%), simplified comprehension (77%), increased student motivation (72%) and promoted correct use of scientific concepts (59.8%). It can therefore be said that CAEx represents a solution, on the one hand, for the student to be more attentive and serious, receive scientific information and engage in the teaching process. On the other hand, the teachers said that they became facilitators in the practical work.

The Disadvantages of Using CAEx

According to most of the respondents, the disadvantages included students relying solely on manually manipulating data on their computer rather than creating their own graphs, neglecting measurement errors, and failing to develop analytical skills. Consequently, students did not become self-reliant and became dependent on this teaching tool.

The Formation of the CAEx

According to the results in Figure 11, most of the physical science teachers surveyed (27%) acquired CAEx knowledge through self-training. However, a small percentage of the respondents acquired this knowledge through the initial training (15.6%) they reported receiving of about 14 hours. Note that 22.1% of the teachers received continuous training in the use of CAEx of about five hours with the education inspector, while 39.3% of the respondents never received training in the use of CAEx in practical work, despite the efforts made, which implies a complete revision of the strategy adopted by the Ministry of Education in the training of pedagogical actors is needed (Mastafi, 2014).

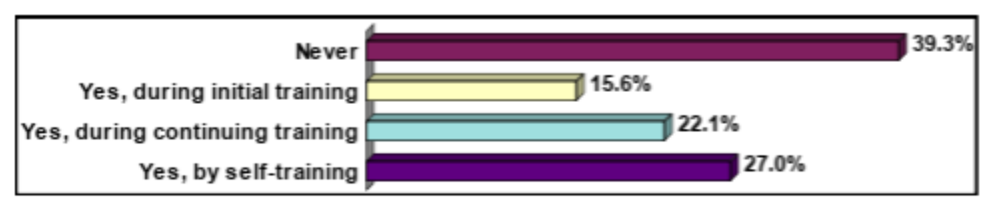

Figure 11: The formation of CAEx

The Mastery of CAEx

However, when it comes to the teachers questioned in our survey, most of them had a level of mastery of CAEx that was, in general, moderately high. Indeed, only 37.7% rated their level of CAEx proficiency as low, with 19.7% as fair, 15.6% as average, 16.4% as good, and 10.7% as excellent (see Figure 12). This was partly due to the low percentage of teachers who had not been trained to use CAEx.

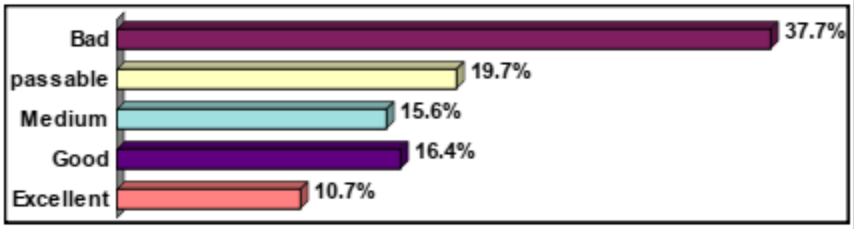

Figure 12: The mastery of CAEx

Barriers to the Use of CAEx

Most teachers confirmed that insufficient training (71.3%), lack of regular maintenance of equipment (73.8%), and too many students (46.7%) remained the major obstacles to the use of CAEx in the classroom. Other problems added to this, such as the lack of specialised software (69.7%), and the lack of equipment in the school (77%), while the lack of time (46.7%) was a minor obstacle to the integration of CAEx (Figure 13).

The directors of high schools also stated that the main obstacles to the general use of ICT by physical science teachers were the lack of training in the field and too many students (Gil-Flores et al., 2017; Messaoudi & Talbi, 2012; Unal & Ozturk, 2012).

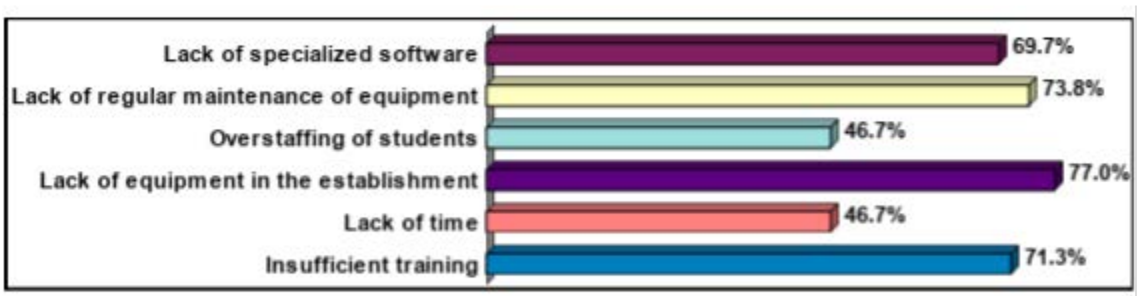

Figure 13: Barriers to the use of CAEx in the classroom by physical science teachers

The Conditions of Use of the CAEx

The data in Table 4 below reveal the essential conditions, according to respondents, for the successful use of CAEx in high school physics. The most interesting conditions reported by respondents to our questionnaire were:

- The number of students should be reduced according to teachers to encourage the use of CAEx. This finding is in line with that of the survey conducted by Alluin et al. (2010), who thought that an excess of students was the main variable that discouraged teachers from using ICT. Therefore, the Ministry of Education must urgently adopt appropriate measures to mitigate the negative impact of too many students on the use of ICT as well as on their pedagogical supervision in Morocco.
- Training (84.4%) was essential for the successful and effective use of CAEx in practical work. Other research has highlighted the fact that teachers' technical competence boosts their confidence in using technological tools, a prerequisite for assessing their performance in terms of technological investment (Leu, 2005).
- Sufficient equipment and the availability of suitable CAEx software were crucial, as indicated by 85.2% of respondents.
- It is worth noting that 80.3 % of respondents said that classrooms should be free of clutter.

Table 4: The Conditions of Use of the CAEx

Conditions	% Response
Have classes with fewer students	80.3 %
Follow a training course	84.4 %
Have the software and equipment	85.2 %

Finally, in addition to the main conditions mentioned above, other elements could encourage the use of CAEx in education in general, such as, the motivation of educational stakeholders to make more efforts, the desire to improve students' academic performance, the pleasure of providing students with high-quality materials, and the wish to increase students' autonomy (Alluin et al., 2010; Aoki et al., 2013).

Discussion

The results of the study highlight a limited pedagogical integration of computer-assisted experimentation (CAEx) systems in physical science teaching and assessment practices within the academy of Fez. This finding is in line with similar observations in the Marrakech and Casablanca academies, as highlighted in studies by Atibi et al. (2017). Several factors contributed to this situation. Firstly, the lack of in-service training for teachers was a major obstacle. Similarly, large class sizes and programme overload limit the possibility of conducting experiments due to time constraints.

Although the Ministry has made efforts to provide CAEx materials to teachers, the results of the study by El Ouargui et al. (2019) highlight that, despite these advances, only about 60% of schools were equipped with these materials. Therefore, there is still an urgent need to increase the quantity and availability of this tool within secondary schools. In addition, it is essential to note that the types of sensors available in schools were unevenly distributed, accentuating disparities in access to quality science education. On the other hand, self-training played a crucial role in the integration of CAEx, underlining the need for greater investment in in-service training programmes tailored to the specific needs of physical science teachers.

The use of CAEx also offers undeniable advantages. It saves time by processing data and generating graphical representations, thus, facilitating the teacher's work during the session. What is more, the use of CAEx makes it possible to measure the benefits for students in terms of concept assimilation (Gourja & Tridane, 2015). Studies by Yusuf and Afolabi (2010) have shown improved student performance when using CAEx, whether individually or collaboratively. However, our research also highlighted a disadvantage of using CAEx as a teaching tool. Students tended to manipulate data manually on the computer and were not encouraged to draw graphs themselves. As a result, they may become dependent on this teaching tool and fail to develop sufficient autonomy.

Conclusion and Recommendations

At the end of this research, we conclude that the results obtained indicate that the use of CAEx in the classroom by teachers for their practical work remains limited. However, it is important to note that most physics teachers showed a keen interest in CAEx. It can be said that CAEx played a crucial role in the understanding and assimilation of scientific concepts, offering a solution for increasing student attention and engagement. In addition, CAEx can foster the development of a sense of initiative among learners.

The results of this research also revealed that the main obstacles to the use of CAEx in physics in high schools in the Moroccan regional academy of Fez-Meknes, as well as in the two provincial directorates of Casablanca and Guercif, were: insufficient training, lack of regular maintenance of equipment, overcrowding of students, lack of specialised software and insufficient equipment in schools.

In order to improve the use of CAEx in the teaching of physics at the secondary level, some perspectives are presented: the excessive number of students per class must be reduced; teachers must be qualified and trained in the pedagogical use of CAEx in the classroom; science teachers must be motivated and encouraged to integrate CAEx in their teaching; schools must be equipped with the necessary and appropriate equipment to carry out practical work with CAEx; and textbooks should be accompanied by guides for practical work with CAEx.

At the end of this research, it is possible to see that the use of CAEx in high school was very practical and it could greatly respond to the expectations of the Ministry of National Education and Vocational Training within the framework of its new orientation towards computerisation and digitalisation of education. Therefore, administrators or educational planners must include CAEx in their programmes for the teaching and learning of physics, so that it becomes mandatory for all high schools.

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